CONTINUOUS ELECTRONIC ON-LINE COOKNESS TESTER FOR POTATOES

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Abstract

An on-line instrument was developed to continuously measure the amount of cooking received by potatoes during processing. It correlates with our earlier work in which a batch back extrusion tester was used to develop a model for cooking. As a prototype, the on-line instrument was used in place of the conventional ricer in the instant potato flake process; but should be applicable to other food processes to optimize the amount of cooking a food product undergoes during processing.

Compendio

Se construyó un instrumento en línea para medir continuamente el grado de cocción de las papas durante su procesamiento. El mismo se correlaciona con nuestro anterior trabajo en el cual fuera utilizado un probador a presión para desarrollar un modelo de cocción. Como un prototipo, el instrumento en línea fue utilizado en lugar del tamiz convencional en el procesamiento instantáneo de hojuelas de papa, pero podría aplicarse a otros productos alimenticios, para optimizar la cantidad de cocimiento que sufren durante el procesamiento.

Introduction

Computer modelling, simulation, expert system control of food processing—the computer revolution of the food processing industry is just over the horizon—or has it arrived? Unfortunately, the missing technology for joining the computer age to the food industry is not the computer software but the instrumentation required to perform routine chemical and physical analyses continuously and on-line (Bibbo, 1986, Kress-Rogers, 1986).

Computer simulation has existed since the late 1950's in the petroleum based industries (Edwards and Baldus, 1977) but only recently have simulators been developed which are useful for the food process industry.

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[1]U.S. Department of Agriculture, ARS, Eastern Regional Research Center, 600 E. Mermaid Lane, Philadelphia, PA 19118.

[2]The mention of firm names or trade products does not imply endorsement or recommendation by the U.S. Department of Agriculture over other firms or similar products not mentioned.

ADDITIONAL KEY WORDS: Texture, mash, extrusion, potato flakes.

Recently, a computer simulation for food processing using the potato flake process as a prototype was developed (Kozempel *et al.*, 1988). Many theoretically based models are included.

At the current state of the art, a food process can be simulated quite accurately. However, sufficient lead time is required to use the simulation program on a process since analytical samples must be taken 1 to 3 days in advance to allow sufficient time for sample prep and analysis. Hence, real time simulation and control are not a reality yet.

Consider a representative food process—the potato flake process. Some typical chemical analyses needed continuously on-line are: total sugars, reducing sugars (glucose and fructose), starch (amylose, amylopectin), minerals (potassium, iron, calcium) and vitamins. Obviously, other analyses would be required for other processes.

Several continuous on-line analyzers are available, *e.g.*, infrared analyzers for moisture, conductivity for ionic concentration, pH and specific ion probes, refractive index meters for concentratons and colorimeters. Each has limitations of temperature, interfering components, concentration ranges. Additional types of instruments are needed.

There are similar requirements for physical measurements. Many physical measurements are made now in a batch, off-line mode. For example, specific gravity and color are routine initial measurements for potatoes before processing. Recently, computer aided defect removal systems were applied to potato processing. This development enhances product quality and greatly reduces labor costs, specifically at trimming and inspection.

Another off-line measurement is texture testing. A back extrusion texture test to develop a model which accurately describes the extent of potato cooking has been used (Kozempel, 1988). A simple index or number indicates how cooked the potatoes are. The purpose of this paper is to describe the development of a continuous, on-line instrument for measuring the degree of cooking of potatoes using the back extrusion texture tester as the basis for the unit.

Materials and Methods

As shown in Figures 1 and 2, the continuous on-line cookness tester consists of a motorized screw press with three load cells equally spaced to measure the screw's reactive force on either a die plate or a solid plate. An accurate measurement of this reactive force was guaranteed by cantilevering the screw in the housing to prevent binding. This cantilevered construction also facilitated the assembly/disassembly, cleaning and the maintenance of sanitary processing conditions.

When the texture measurement device is used in the ricing version (Figure 1 and the right half of Figure 2) the die plate is centered in the die plate supporting the end plate which, in turn, is centered on the barrel portion of the housing. The barrel was enclosed by three (equally spaced) guide bushings for guiding three tension rods which are attached to load cells. The other ends of the load cells are rigidly attached to the flange on the housing with bolts. The ends of the tension rods that extended through the guide bushings are threaded. Thus, the rods can be preloaded with a predetermined force using nuts on each end.

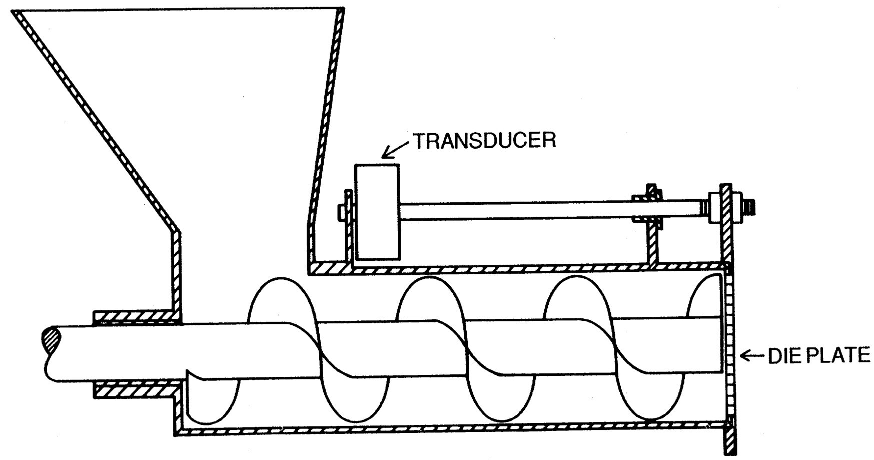

FIG. 1. Elevation view of the texture measurement instrument, ricing version.

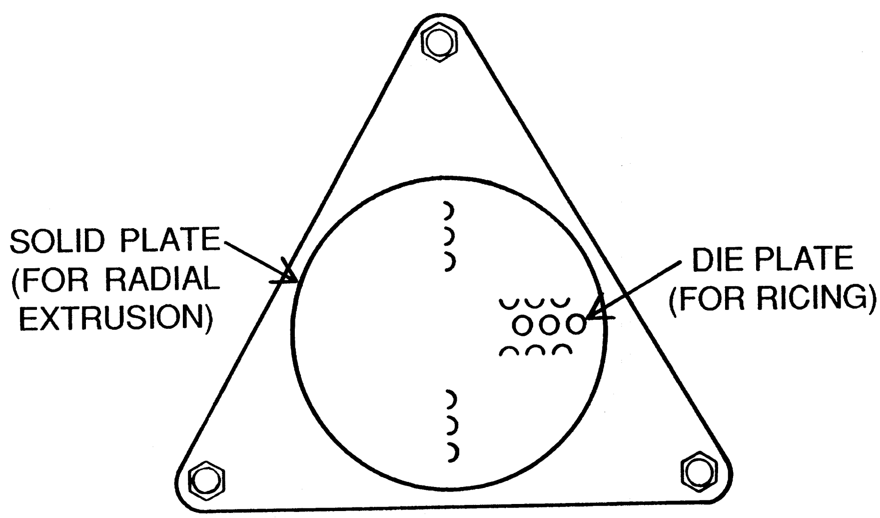

FIG. 2. End view of the texture measurement instrument.

During operation of the ricer, the force required to extrude the potato mash through ninety-six 4 mm dia. holes in the die plate is applied to the potato pieces by the screw. This active force of the screw causes an equal but opposite reactive force in the die plate and the mash. This reactive force is related to the degree of cooking and transmitted to the three load cells by the die plate and tension rods.

The load cells yield an electrical output signal proportional to the applied load force. The output signals were recorded electronically. The load cells were calibrated using standard weights suspended from the load cells. Calibration readings for the load cells were taken electronically as measured in actual use.

When the device is used in the radial extrusion version (left half of Figure 2), the die plate is replaced with a solid plate. The solid plate is centered in the end plate and positioned a predetermined distance (4 mm) from the end of the barrel portion of the housing. The outside diameter of the solid plate matched the outside diameter of the barrel, thus forming a radial extrusion slot.

When in operation the screw applies the force required to radially extrude the mashed potato pieces through the slot. This active force by the screw caused an equal but opposite reactive force in the solid plate. As in the ricing version, this reactive force is transmitted to the three load cells by the tension rods. Detailed drawings are available from the authors.

The pilot plant potato flake process on which the unit was developed and tested is described by Kozempel, *et al.* (1988).

Texture tests were performed with a Food Texture Corp. testing machine, model TP2[2] (Food Texture Corp., Rockville, MD) with a model FTA-300 force transducer (Kozempel, 1988). Samples were tested by performing back extrusion texture measurements. Back extrusion uses a piston and cylinder test apparatus. Sample was placed in the cup and the piston forced into the sample at a constant speed. The unit was designed with a set annular clearance between the piston and cylinder wall. The sample extruding in the annular space is a measurement of the texture.

The test cell was 53.2 mm diameter and 76.2 mm deep. The piston was 45.2 mm diameter resulting in an annular clearance of 4 mm. The stroke depth was 65.1 mm (11.1 mm bottom clearance) and the stroke rate was 6.8 mm/sec. Potatoes were processed as nominal 1 cm dice. Potatoes for testing were placed in a 27°C water bath for 3 minutes to standardize the texture test temperature. Four to six tests were made on each sample of potatoes and the average peak force recorded as texture.

Results and Discussion

Back extrusion of potatoes employing an FTC texture tester measured the amount of potato cooking. A linear relationship between measurements on the continuous, on-line texture tester and those measured by the FTC unit would prove that this continuous, on-line unit gives a valid indication of the degree of cooking of potatoes.

We made a series of runs in the pilot plant potato flake process in which we changed the cooking time via the belt speed in the cooker. Readings from the continuous unit were taken for each different cook time every 4 sec. (on a computer tie-in) for 10 minutes. Each point was the sum of the forces measured on three load cells. The average forces for the 10-minute periods were plotted vesus the texture readings in the FTC unit. Experiments were run with the die plate (ricing) and the solid plate (extruding). The FTC measurements for potatoes leaving the steam cooker ranged from approximately 200-500 Newtons. The cooking model for potatoes was developed over the range of 175-1100 Newtons.

The results are shown in Figure 3. As can be seen, the two units correlated very well. For the solid plate, the empirical equation of the line is: $F = 318.1 + 1.048 \times$ (FTC reading), with a correlation coefficient of 0.973. For the die plate, the equation is: $F = 31.2 + 0.979 \times$ (FTC reading), with a correlation coefficient of 0.996. There was a different equation for each line because the total open cross sectional area was different for each plate and the exact method of extrusion, radial or forward, was different. Such a high degree of correlation indicated the continuous, on-line texture tester accurately measures the degree of cooking of potatoes.

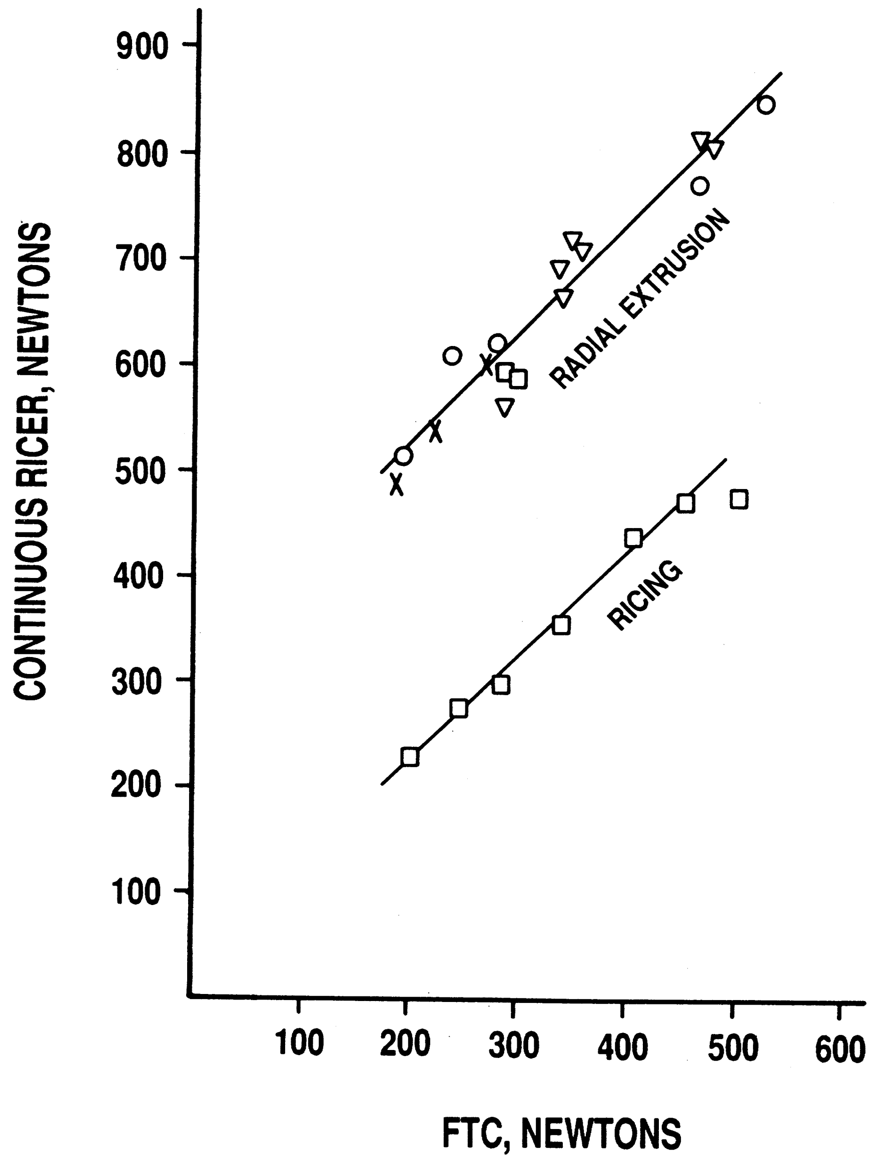

FIG. 3. Plot of texture measurements on the continuous on-line texture measurement instrument vs. FTC measurement.

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